TURBULENT PRESSURE MEASUREMENTS ABOVE THE AIR-SEA INTERFACE

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LONG TERM GOALS

To improve our understanding of fundamental air-sea interaction processes dependent on turbulent and wave-scale pressure fluctuations.

OBJECTIVES

Our objectives are threefold:

(1) To develop new and more accurate instrumentation for the measurement of turbulent pressure fluctuations in marine environments.

(2) To improve our understanding of the fundamental role played by turbulent pressure fluctuations in the marine surface layer turbulent kinetic energy balance.

(3) To improve our understanding of the role of pressure fluctuations in wind-wave generation, and to develop new parameterizations of this process.

APPROACH

We are analyzing field data in an attempt to answer fundamental questions about the role of turbulent pressure fluctuations in determining the structure of the marine surface layer. The field data comes from three separate campaigns: RASEX (Riso Air-Sea Experiment), undertaken at the Riso off-shore sea-mast at Vindeby, Denmark; during the MBL-ARI FLIP cruise off Monterey, California; and during the COPE (Coastal Ocean Probing Experiment) FLIP cruise off the Oregon coast. In each of these field campaigns quad-disk pressure probes (Nishiyama and Bedard, 1991) were used, which have previously been shown to be capable of making reliable

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turbulent pressure measurements (Wyngaard et al., 1994).

For the Riso experiments, a tower located 2 km off-shore was instrumented with multiple levels of sonic anemometers and turbulent pressure probes. Directly below these instruments was a three-wire wave staff. By calculating covariances between the sonic anemometers, pressure probes, and wave wires, we have been able to evaluate terms in the turbulent kinetic energy equation as well as determine the wave phase-dependent structure of turbulence profiles.

For the two FLIP cruises multiple levels of quad-disk pressure probes were again deployed together with sonic anemometers, together with either a single or an array of wave wires.

WORK COMPLETED

For the Riso data sets, the wave directional spectrum was calculated for each run using the three wave wires, using the technique of Hanson et al. (1997). The wave directional spectrum was then used to determine periods when the wave and wind directions were aligned or when they differed significantly, and the effects of the wind-wave alignment on the TKE budget was evaluated (Wilczak et al., 1997).

A simple statistical similarity hypothesis was developed for scaling of turbulence parameters above surface waves. This scaling hypothesis was first tested on the Riso data (Hare et al., 1997a) and was later applied to the COPE and MBL-ARI FLIP data sets (Hare et al., 1997b)

Transfer coefficients for heat were computed for the Riso data, and the effects of internal boundary layers for off-shore flow were estimated (Mahrt et al., 1997).

RESULTS

If the Riso TKE analysis is restricted to periods of steady wind directions, the pressure and turbulent transport terms in the TKE budget are found to be opposite in sign, with the pressure transport acting as a gain of TKE and the turbulent transport acting as a loss. The magnitudes of these two terms increases as the surface layer becomes more unstably stratified (increasing -z/L). Importantly, at neutral stratification, the two terms do not individually approach zero, nor does their sum. At neutral, the transport term remains a loss of about 18% of the shear production term, and the pressure transport remains a gain, equal to about 50% of the shear production. These results are in excellent agreement with the budget imbalance study of Hogstrom (1990). For steady winds, the neutral drag coefficient displays little variability, with a value of $C_{DN} = 1.3 \times 10^{-3}$, and the wave age is also near constant with a value of $C_p/u_* = 14$.

If the analysis includes periods when the winds are not steady, so that the wind and wave directions differ, imbalances are created in the TKE budget terms. In addition, the 10 m neutral drag coefficient and wave age change as well. For periods with accelerating winds and large differences (> 40 degrees) in wind and wave directions, the drag coefficient is largest, with $C_{DN} = 4.0 \times 10^{-3}$. For periods with accelerating winds but small differences in wind and wave directions, the drag coefficient increases only marginally, to about 1.5×10^{-3}. The changes to the turbulent and pressure transport terms can be very large in these unsteady conditions, and they

can even change sign.

The wave-similarity study has shown that, when compared to theory, simple extrapolation of the wave-induced pressure field from a fixed height to the surface may contribute to the uncertainty of the measured growth rates.

The Riso heat transfer analysis has shown that the thermal roughness length has only a weak dependence on sea state, but that it is strongly dependent on the depth of the internal boundary layer.

IMPACT

The TKE budget study has the potential to significantly impact surface and boundary layer models that incorporate TKE-based parameterizations of turbulence flux profiles. The wave-similarity study provides a framework for evaluating or modeling wave-induced effects on turbulence structure in the marine surface layer, as well as for evaluating the wave growth parameter. The coastal heat flux study primarily will have an impact on very high resolution models whose goal is to predict turbulence profiles in the very near-shore coastal zone.

TRANSITION

None.

RELATED PROJECTS

None.

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